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# Structured and Inhibited Mixing on the Continental Shelf

Timothy F. Duda

Applied Ocean Physics and Engineering Department, MS 11  
Woods Hole Oceanographic Institution, Woods Hole, MA 02543  
phone: (508) 289-2495 fax: (508) 457-2194 email: [tduda@whoi.edu](mailto:tduda@whoi.edu)

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## Final Project Report

### LONG TERM GOALS

A goal is to understand diapycnal mixing process during the stratified summer season in the temperate continental shelf environment. This understanding is required to correctly account for the effects of mixing in coastal ocean models. These effects influence modeled (and actual) density fields, and thus flows, as well as modeled and actual distributions of dissolved and suspended material.

### OBJECTIVES

The objective of this project was to determine whether intermittent diapycnal mixing events (i.e. turbulent events that cause cross-isopycnal mass flux) are sensitive to the background conditions in a specific way. The hypothesis is that, within a field exhibiting a step-like density structure, mixing will be more rapid in less-stratified layers than in more stratified interfaces. Such an effect would cause density-gradient perturbations to grow, an effect sometimes known as the Phillips instability (Phillips, 1972; see also Balmforth et al 1998). This behavior is analogous to a negative eddy diffusivity  $K$ . Evidence of gradient-dependent  $K$  was found in the ONR Coastal Mixing and Optics (CMO) program dye diffusion studies, and in towed-microscale conductivity measurements obtained in conjunction with the dye studies (Duda and Rehmann, 2002). We wish to expand on the CMO work by obtaining and using more data of better quality than previously available, confirming and/or improving the result.

### APPROACH

An extensive set of microscale conductivity data and supporting data were obtained with a towed sensor package (called Micro-Tow, MT) during a seven-day research cruise on *RV Endeavor* during August 2004. The towed platform and the onboard data-acquisition electronics were of our own design.

The measured conductivity gradient variance, which should be proportional to temperature gradient variance and to  $\chi$ , the thermal dissipation rate, can be compared to the vertical temperature gradient, with both estimated over short time intervals. A definitive correlation of the two quantities, and a relationship with a smaller exponent than  $\chi$  proportional to  $dT/dz$

to the first power would indicate eddy diffusivity  $K$  inversely dependent on the gradient, supporting the Phillips instability.

## **WORK COMPLETED**

The field program was carried out August 8-14, 2004. This was RV Endeavor cruise EN396, sailing from/to Narragansett, RI. This ship is operated by the University of Rhode Island. All systems functioned well during the cruise. The MT system was in the water collecting data for approximately 92 hours, representing 60% of the time at sea (Figure 1). For an additional 27 hours we collected data with the University of Rhode Island automatic undulating Scanfish system, which we specially equipped with microstructure sensors through a collaboration with the Naval Research Laboratory (Dr. David Walsh).

We had partial success at staying in water with a desirable near-zero salinity gradient. We believe that for most of the time we remained in water with small enough salinity gradient to require only small correction factors in our analysis.

Prior to the field work, the existing towed conductivity vehicle was upgraded to carry a second microstructure sensor. Also, new ship-board data acquisition and data-visualization reporting software was written.

## **RESULTS**

Data acquisition results were excellent. All towed systems and ship-board systems worked well for the duration of the experiment. Most if not all of the data appear to be usable and of excellent quality. Figure 2 shows example temperature, salinity, and conductivity gradient variance from one transect.

There were two impediments that prevented finalization of a publication of results in a journal article during the course of the project. First, we had trouble successfully locating water with low salinity gradient and with doubly-diffusively stable stratification, which would ensure lowest possible analysis errors and the smallest error bars. Thus, extra work is required to improve statistical reliability beyond that of our existing publication. The data must be culled and gone over in additional ways to extract the best data and compute a new  $\chi$  - to - vertical temperature gradient correlation result. Next, loss of communication synchronization between submerged vehicle and ship-board PC caused anomalies in the data stream which required extra time to work around. Thus, final correlations and investigation were not obtained.

## **TRANSITIONS**

The tow platform built by us for this type of work has been used by Naval Research Laboratory personnel in conjunction with monostatic high-frequency flow-visualization acoustics to study nonlinear internal gravity waves in the South China Sea. In addition, NRL has built a sensor package to make towed microscale measurements, similar to our measurements, in order to study mixing processes in coastal and near-surface waters. This is the sensor package that was appended to the auto-undulating Scanfish during our cruise.

## REFERENCES

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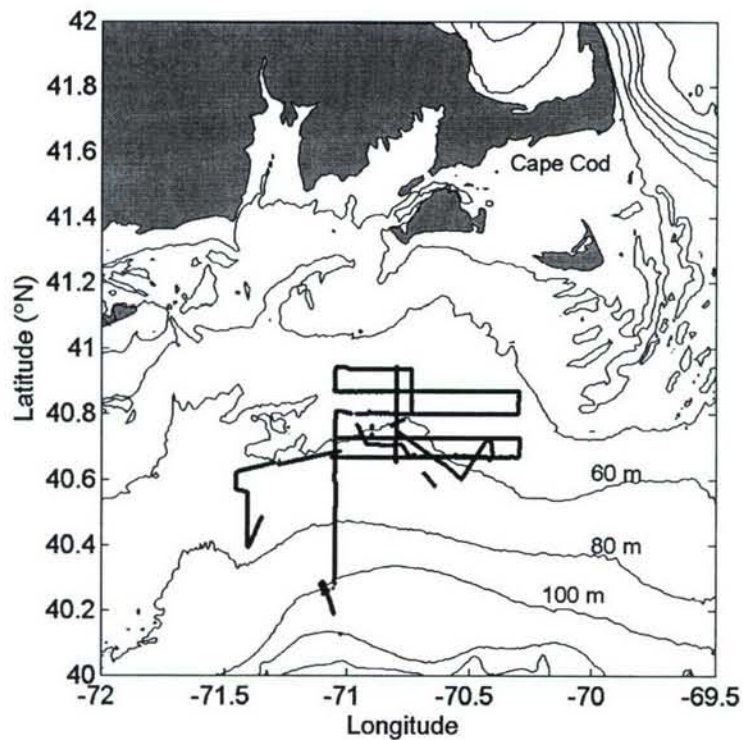


Figure 1: Track lines of Endeavor along which MT data were collected on the continental shelf south of New England.